THE STRUCTURE OF THE DIATOM GIRDLE.

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Usually the girdle of the diatom is easily separated from the valve to which it pertains. A strewn mount of cleaned diatoms will show most of the girdles so separated. If any doubt as to the structural distinction between valve and girdle were possible previously, Printz removed it, so far as the large forms of *Navicula* were concerned, by his study of sections.[1] The girdle, therefore, is understood to be, not a part of the valve, but a closed hoop of silica, more or less narrow, wedged into the rim of the valve or otherwise held in place not very firmly. Deby even asserts that in the case of many species old girdles are "caducous" and detach themselves spontaneously. The account[2] which this author gives of the process of multiplication by cell-division—an account agreeing in the main with the views of diatomists in general—implies a rapid and necessary decrease in size as an inevitable result. So also Pfitzer[3] and, following him, most writers on diatoms. The closed hoop structure is taken as typical of the whole family by such recent writers as F. Schuett[4] and George Karsten,[5] the former of whom, discoursing upon the "Zwischenbaender" of O. Mueller, remarks: ". . . . die Zwischenbaender sind . . . . nach *Art der Guertelbaender als geschlossene Ringe* ausgebildet, und erscheinen dann als secundaere Guertelbaender, oder," etc.; and

[1] W. Printz: "Études sur coupes de diatomeés observeés dans les lames minces de la roche de Nykjobing," Brussells, 1880.

[2] J. Deby: "Ce que c'est qu'une Diatomeé?" Soc. B. de Microscopie, Bruxelles, 1877.

[3] E. Pfitzer: "Untersuchungen ueber Bau und Entwickelung der Bacillariaceen," Bonn, 1871. Also, "Die Bacillariaceen," *Encyklopaedie der Naturwissenschaften. Botanik*, II, p. 435, where the matter is thus tersely expressed: ". . . . bei jeder Theilung die groessere der beiden entstehenden Tochterzellen genau eben so lang ist, als die Mutterzelle war, waehrend die andere etwa um die doppelte Dicke des Guertelbandes kuerzer ist."

[4] F. Schuett: "Bacillariaceæ." Engler and Prantl's *Pflanzenfamilien*, I, 1, b., p. 39, 1896.

[5] George Karsten: "Die Diatomeen der Kieler Bucht," *Wissenschaftliche Meeresuntersuchungen*, Vierter Band., 1899.

the latter simply takes the closed ring structure for granted. This structure being admitted, the deduction as to progressive decrease in size is undoubtedly sound. In point of fact, wide variations in size do, in the case of a vast number of species, occur continually. In filamentous forms it would appear that a decrease does occur step by step with the process of reduplication. Yet facts are not wanting that do not agree altogether with the theory. The demonstration has seemed to demonstrate too much. "If the matter is as simple as Mr. Deby has made it out to be," writes Van Heurck, "sexual reproduction would be very frequently observed, which, however, is not the case."[6] Possibly what is meant here is not exclusively sexual reproduction, that is to say conjugation (which does not, in the algæ, wait upon decrease in size), but also rejuvenescence of the cell by auxospore formation.

The scarcity of auxospores in *Melosira* and similar forms, compared with the number theoretically called for, is one of the striking facts in this connection. The details of the process of reduplication were therefore studied exhaustively by Otto Mueller[7] in the case of a single species of the genus. The study culminated in the celebrated "law of Mueller," a statement of the sequence of events in the growth of this particular species, which shows why it is that after forty-three successive reduplications there is but one auxospore in place of the 1,052,100,000,000 which ought to produce themselves according to the theory of plain geometrical subdivision.

Studies of the character of this upon *Melosira arenaria* are not so plentiful that we should desire to do aught but award it the high appreciation which is its just due, and which it has compelled from diatom students in general.

We must, however, be allowed to remark that it has yet to be shown that the sequence of events is the same in all species; and, further, that it is not quite certain, as will appear later, that even the fundamental structure of the silicious parts is the same in all the genera and species of the diatoms.

In all the literature upon diatoms with which we are familiar

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[6] H. Van Heurck: *Treatise on the Diatomaceæ*. English translation by W. E. Baxter, London, 1896.

[7] "Die Zellhaut und des Gesetz der Zelltheilung folge von *Melosira arenaria* Moore," Berlin, 1883.

there is noticeable a curious tendency to neglect the structure of the girdle, to take for granted that it is everywhere the same, and that it is typically a closed hoop.[8] Only in the Lauderiinæ and Rhizosoleniinæ, which include the genera *Lauderia, Guinardia, Rhizosolenia, Dactyliosolin,* and one or two others, is any other structure figured or described; and in those cases a distinction is made by calling the numerous girdles either annulæ or interbands. In short, the girdles here are considered non-typical and peculiar.

Peculiar in certain aspects they may be. But that either these "annulæ" or the "Zwischenbaender" in other genera, differ from the usual girdle in being incomplete hoops is a proposition we dare to call in question. Our theme may be stated thus: *The closed hoop structure is unusual.* With some very important exceptions, the girdle is a two-ended band of silica, with the ends variously and characteristically rounded or otherwise modified, and approximated or overlapping without being joined. The position of the gap or joint is, within limits, constant in a given genus with relation to salient features of the valves. In case of each simple pair of primary girdles, the two gaps are usually at opposite points of the diatom; and in general, in the forms we have studied, the gaps are normally so situated with respect to each other as to "lap joints."

In calling attention to a fact at once so elementary and fundamental, and so in opposition to views generally held, we could desire to present a large number of particulars. But we cannot claim the merit of setting forth at this time the results of any adequate study of the girdle. The field is vast, and the difficulties are various. We content ourselves now with the presentation of certain typical examples, mainly or almost exclusively among the larger forms. It seems, indeed, almost or quite safe to infer the main structure of the girdles of minute species from the main structure of those of larger species in the same genus.

The facts presented are almost all morphological and static, and so, however incomplete in some respects, they have the advantage of being easily verified by any student of the Diatomaceæ. Our observations have been primarily among the Pennatæ, and first of

[8] This is by no means to ignore the "Zwischenband" developments of Otto Mueller and F. Schuett. But, as we have shown, the latter authority at least implies the closed-ring girdle structure. The "Zwischenband" is somewhat apart from our present subject, which confines itself to girdles proper.

all in the genus *Surirella*. It therefore seems necessary to begin with this genus—a genus that partakes of some of the characteristics of both Pennatæ and Centricæ. Especially in the location of the girdle gap would *Surirella* seem to be anything but a typical member of the Pennatæ. Following this we shall consider the Pennatae, and lastly certain typical Centricæ.

SURIRELLA.

It was a study of a pure and very large gathering of *Surirella elegans* Ehrenb. that first drew our attention to the real structure of the girdle. The diatom was found in greatest abundance, practically free from other forms and from inert matter, in a shaded rill of cold water during the month of August. It formed a dark-brown or even blackish patch upon the bottom, about a foot in diameter and more than a fourth of an inch deep. Several ounces of purest material were dipped up and placed in bottles. Some of the gathering remained in good living condition for four months. A part was boiled in strong nitric acid, and mounts were made in balsam. Girdles separated from their valves were plentiful in these preparations. Many girdles were broken into several pieces, but many more were uninjured. Those latter, however, always showed an opening that was not a break. Though separated from their valves, the girdles remained in general bent nearly as when attached. In every case, with absolutely no real exception, the gap was on one of the flat sides of the oval, and mostly not far from a point midway of the length. This was true of all the girdles, of which there were two main types observable. The first of these is the mature girdle, mostly broad and thick; and the second is the young or immature, narrow and thin. The latter kind, in addition to the gap, showed also, at a point nearly opposite, a little stem or *cleat* of silica, in shape somewhat like an hour-glass, extending at right angles from the edge to a distance equal to or greater than the breadth of the girdle itself. This cleat was absent in older, or what may be called primary, girdles. The gathering was, and long remained, rather quiescent as respects reduplication, and successive preparations continued to show the two kinds of girdles with practically no intermediate gradations. These two kinds are represented at *d* and *e*, fig. 1, Pl. XV. It being manifestly impossible to understand the relations of these

girdles to each other and to the valves when the elements were in this state of dislocation, preparations were made with parts *in situ* by burning the crude frustules upon cover-glasses and mounting dry and in balsam.

Persistent study of all those preparations, as well as of living frustules and mounts made by other preparers, has, most unfortunately, left many points still obscure. Yet we are able to present the following definitely ascertained facts.

The complete frustule, in this gathering, shows first of all two broad and thick primary girdles, the inner and the outer. Each of these exhibits a gap between its approximated ends, substantially as shown in diagram *c*, fig. 1, Pl. XV.

These gaps are on opposite sides of the diatom in every case observed by us; and while the exact location varies, it is always between the smaller end and the middle point of the length.

Long before there is any other evidence of coming reduplication, two secondary girdles make their appearance, one for each of the primary girdles. One of these extends as a narrow, thin band around the edge of the outer primary, and projects a cleat through the opening in the primary, attaching itself thereby to the outer valve. This outer secondary girdle shows in optical section at the end of the diatom, as if attached to the inner edge of the primary. At the same time, upon the edge of the inner primary girdle appears in like manner a secondary growth, with cleat extending through the opening in the primary to the inner valve. But in optical section, at the end of the diatom, this inner secondary appears as an *outward* thickening, as if attached to the outer edge of the primary. We have, therefore, now four girdles, the two primary and the two secondary, for each pair of valves. Diagrams of these parts, separated and in contact with each other, are included in fig 1, Pl. XV.

That which arrests attention is, that the inner secondary girdle apparently overlaps the inner primary. If these secondary girdles are, by any possibility, destined to become primary girdles in the daughter-cells, the arrangement as described will admit of but two results: either the new valve will attach itself to the new girdle, the old valve remaining as before the inner or smaller valve of the two, or, on the other hand, the new valve may join to the old girdle, which parts from the old valve and is replaced by the new girdle.

But that the secondary girdles do develop and function in either of these ways is what we have been quite unable to prove. It is next to impossible to trace the disposition of parts in a frustule of *Surirella* after the two new valves have formed and before the daughter-cells have parted company. We can only say that we have looked carefully, but hitherto in vain, for any evidence of the growth of new girdles from the young valves of *Surirella elegans* in accordance with orthodox views. In some other genera we have observed facts that seem to indicate that similar secondary girdles, formed before the young valves, broaden and lose their cleats, becoming finally indistinguishable from primary girdles. In the case of *Surirella* we are more in doubt, and we desire to pursue the subject further. As bearing on the doctrine of a necessary decrease in size during successive cell-divisions, the matter is plainly of importance. And in the same connection we would state that among the millions of frustules in our gathering of *S. elegans*, products of a long series of divisions and redivisions, the small ones were few compared with those well toward the maximum of 220 μ. It would certainly seem that, with the expansible girdles which pertain to this species, new valves might be formed as large as the old; and that the quite small frustules, 170 μ long, which are present only to the extent of ten per cent., must owe their existence to some less familiar and simple, but more real, influence than a supposed, but non-existent, stony inexpansibility of the mother-cell girdle.

The girdles of *Surirella elegans* are apparently hyaline, but under favorable conditions transverse striæ are visible. When well resolved, the appearance is similar to that of *Amphipleura pellucida*, but the striæ are more delicate and the resolution much more difficult. Attempts further to resolve into dots were unsuccessful.

Pure gatherings of *S. splendida* Kuetz, less rich than that above described, yet ample, showed essentially the same girdle structure. That is to say, there were primary and secondary girdles, the latter with and the former without cleats, but both with gaps situated as in *S. elegans*.[9]

[9] Many mixed mounts of diatoms were examined, and *Surirella* girdles of several species were recognized. All showed lateral gaps, and many secondary girdles were seen with cleats. In Mueller's type-plate of one hundred forms in styrax, a lateral gap was observed in the form listed as *S. norwegica*, Eul. (II, 3).

S. elegans may stand as a type, not of its own genus only, bu apparently also of the Surirelloideæ. *Cymatopleura solia* W. Sm., according to our too few observations, has girdles with gaps situated one on each side of the diatom, not far from the place of greatest constriction midway of the length. As for *Campylodiscus*, the remaining genus, we have been unable to find any preparations showing girdles in a condition admitting of study.

NITZSCHIA.

We have not been fortunate enough to identify satisfactorily any large variety of girdles in this genus. Such girdles as are *in situ* show nothing of importance except occasionally certain apparent lines running out at a sharp angle from the termination of the valve on the girdle face—such as have been figured frequently (*e.g.*, *Nitzschia linearis*, in Van Heurck, Pl. 16, fig. 542). Dislocated girdles, however, were found plentifully in a gathering of *N. sigmoidea*. As in *Surirella*, the girdles are of two kinds. The first is, when in place, in contact with its valve along its whole length. The second is narrower, and connected with the valve only at one point—the cleat. Both have one end open, the other end closed. The free ends of a girdle are uniformly beveled in a characteristic way, so as to form two sharp points. These points meet each other at the end of the diatom. The inner girdle of a simple pair has its opening at the end opposite to the opening in the outer. The cleat on the secondary girdle is situated at the opening in the primary, and partly closes it without at any time fusing it into a solid, unbroken band. Fig. 5, *a* and *b*, Pl. XV, illustrate these two forms of girdle in this species very well, except that breadth is less in proportion to length than these drawings would indicate.

NAVICULA.

Among the vast number of species of this genus we have paid attention mostly to the Pinnularia group, such as *Navicula viridis*, *nobilis* and *major*. Pure gatherings of these large forms have not been at our command. But though nowhere in great abundance, some are to be found in almost all good fresh-water gatherings. The girdles are easily assigned to their proper species as a rule, because even when quite detached they generally still retain approximately their original shapes. Even in fossil deposits it is

not difficult to recognize many *Navicula* girdles as belonging to this or that particular form also represented therein by valves.

In these large forms the girdles, when viewed as they stand upon their edges—that is, in valve view, but with valve removed—show each one a closed end and an end more or less widely opened. When the exact shape is retained, the free ends, which are much thinned or drawn out, approach each other closely or perhaps overlap a very little in some cases. As a rule, however, some little distortion occurs during the preparation of the slide. A diagram of the edge-view is given in fig. 2*a*, Pl. XV.

When seen flatwise, or in girdle view, the ends are found to be narrowed in the other direction also. When the heat used in mounting has been particularly high, it often happens that girdles lying on their sides are softened, and the preparation will then sometimes show both the free ends nearly or quite in the same place, and not superposed. The appearance then is somewhat as in fig. 2*b*, Pl. XV. The terminations of the band of silica appear always of nearly this same shape in the large Naviculæ. The joint which is formed by them is uniformly at the end of the diatom; and, as may be expected, the joint or gap in the outer girdle is at one end of the diatom, while that in the inner girdle is at the other end. Secondary girdles, homologous with those described above for *Surirella*, we have seen but in a single doubtful case; and anything resembling a cleat, either *in situ* or detached from the valve, is equally hard to find. Richer gatherings will probably be necessary before the secondary girdles, if such exist in *Navicula*, can be described.

The terminal gap or joint of these large forms is typical of the girdle structure of the whole vast genus. *N. gibba* Kg., *N. Bombus* Ehr., and many others, some in nearly pure gatherings, yield girdles with gaps situated at the ends. It is, indeed, very striking to see how uniformly the dislocated girdles of all species, even the smallest, are open at one end and closed at the other. Girdles *in situ*, unless happily broken at the right place, do not show the gap satisfactorily; and even a pair of girdles, one within the other, with valves removed, often cling together so tightly that the gaps are not obvious, and the observer might think he had here a completely closed single hoop. But a real case of a single girdle with both ends closed has not, among either large or small forms of this genus, been noted by us.

STAURONEIS.

The girdles of *S. Phœnicentron* Ehr. are very thin and narrow, and the free ends forming the gap, which is situated at the end of the frustule, have a less constant and definite shape than in the case of most diatoms. Owing to their tenuity, and consequent proneness to soften and become distorted, these girdles are not easily identified in mixed gatherings. From an examination of some pure gatherings we are able to state that the gaps in inner and outer girdles are at opposite ends of the diatom, and that exceedingly minute cleats are often present on secondary girdles. These cleats are merely little rod-like projections at right angles to the edges of the girdles.

NAVICULOIDEÆ and ACHNANTHOIDEÆ.

Terminal gaps in the girdles of the following have been observed with uniformity: *Pleurosigma angulatum* W. Sm., *Pl. Spencerii* Bailey, *Pl. Balticum* W. Sm., *Pl. elongatum* W. Sm., *Pl. strigosum* W. Sm., *Van Heurckia rhomboides* Breb., *Gomphonema geminatum* (Lyngb.) Ag., *Rhoicosphenia curvatum* (Kuetz) Grun. In the case of *Pleurosigma*, the termination of the free end of the girdle is somewhat like that in species of *Nitzschia*, but less sharply pointed, and more rounded on the side of the termination away from the valve. In the above genera we have not seen any very definite cleats.

Cymbella, *Amphora*, *Amphiprora* and *Mastogloia* remain uninvestigated. *Epithemia* has claimed our attention without yielding any clear understanding of its girdle structure. *Achnanthes brevipes* Ag. and *Cocconeis Pediculus* Ehr. yield girdles in which terminal gaps can generally be distinctly seen.

RHABDONEMA.

Among the crowd of genera and species of the Fragilarioideæ, *Rhabdonema adriaticum* Kuetz. is the form that most clearly shows the essential structure of the girdle. This structure seems, in addition, typical of the whole group, with the exception, apparently, of some species of *Synedra*. Practically the same arrangement—apart from the interposition of the *Zwischenbaender*—is found with clearness in *Eunotia*, and indicated sufficiently in *Meridion*, *Diatoma* and *Fragilaria*.

Two girdles of *R. adriaticum* are shown in fig. 3, Pl. XV. One bears a thin band which joins it throughout its length to the valve or *Zwischenband.* The other is more narrow, and connects with the valve only by the very distinct cleat. Intergradations are observable in rich gatherings which show a gradual increase of breadth, starting from the cleat and extending toward the open end. The ends are rounded, and half-inclined to be spatulate on the side removed from the valve, but come to a point on the side next the valve. The cleat is of considerable breadth, comparatively heavy, and calculated, from its shape, to fit snugly on the inner edge of the valve at the end. A few specimens, only partly dislocated during mounting, showed the usual alternation of parts—that is, the outer girdle of a pair is open at one end of the diatom, the inner girdle of the same pair is open at the other end.

EUNOTIA.

E. major Rab. was studied at some length, both mounted in filaments and mounted after disruption and separation of parts. The mounted filament yields but unsatisfactory results. The features of importance being at the ends of the cells, and the parts being here so overlapped and confusing, an optical section of the end of the cell, especially of one in course of division, will show "a mass of things, but nothing distinctly." Nevertheless, a rapidly growing filament does afford some evidence that prevalent ideas as to what goes on during cell-division of diatoms are not altogether unmixed with error. We desire to return to this subject at no distant date. For our present purpose, we simply show, in fig. 4, Pl. XV, two separated girdles of this species. We have been able to discover no other kind of girdle than these, and such as are of an intermediate character, either in this species or in others of the genus. Filamentous and non-filamentous, all species examined yield only girdles open at one end and closed at the other.

MELOSIRA.

The fresh-water species of this genus are mostly small, and the girdles are, previous to the formation of new valves, excessively tenuous—so much so that any structure is only to be made out with the greatest difficulty. *M. Roeseana* Rab., however, occasionally shows a typical structure, which is also dimly seen in certain speci-

mens of *M. varians* Ag. The long, tubular "connective" which separates the old valves, and within which new valves grow, is made up of numerous imbricated hoops. Each of these hoops is incomplete. The openings in them are situated with respect to each other somewhat irregularly. The species *M. Borreri* Grev., being much larger, reveals a distinct structure. The arrangement of the hoops is essentially like that in *Lauderia annulata* Cleve.[10] These bands or hoops, when separated, show openings; and in a few cases, in the species *M. Roeseana*, delicate cleats extending to the valves have been seen. These cleats are much like those in *Biddulphia*, which are described below. After the formation of the new valves within this system of rings, the tube seems to increase in thickness, and to become more or less firmly united with the outer surfaces or edges of the valves into a stiff and stout construction not easily separated again. So the filamentous state is conserved. But the openings or joints in the rings can still be made out, with proper management. The tube composed by these rings is, therefore, originally somewhat expansible. If it becomes non-yielding, that is after the formation of the new valves; so that, if these latter are smaller, as they undoubtedly are, this fact also has possibly another explanation. Numerous published figures indicate the rings composing the tube in *Melosira* and its relatives, but the openings and cleats have not been figured so far as we can find.

We have not investigated the girdles of the other genera of Melosirinæ nor those of the Sceletoneminæ.

COSCINODISCUS.

Particularly distinct structures are to be found in the girdles of this genus. In fig. 7, Pl. XV, is shown diagrammatically a pair of girdles of *C. subtilis* Grun. with two secondary girdles in place. In fig. 8, Pl. XV, is given an inner primary, with two secondaries adhering. These two figures will sufficiently elucidate the arrangement and relation of parts in this species. We have here the openings in all the girdles and stem-like cleats joining the secondary girdles to the valves. It is worthy of note that here, at least, whatever the import may be, the secondary girdles both

[10] See Van Heurck, *Treatise on the Diatomaceæ*, p. 418. Figure in the text.

overlie the inner primary. Here again, however, our information is incomplete. It is a question whether these secondary girdles are destined to serve the yet unformed valves of the daughter-cells, or whether they are nearly constant features of the mature mother-cell, and designed simply to strengthen the whole structure. We desire to pursue this inquiry further.

A somewhat similar structure is that in *C. robustus* Grev. (at least as to the primary girdle), but more pronounced owing to the greater thickness of the girdle, as will be noted in figs. 1 and 2 of Pl. XVI, which show photographically both views of the opening in the primary girdle. Here the cellular structure of the girdle, which is similar to but much finer than that of the valve, has comparatively broad hyaline margins continuous through the gap. We have observed secondary girdles with cleats in this same species, but not in a shape to indicate clearly their relations with primary girdles.

The structure and arrangement as given will probably explain the form described by J. Brun[11] under the name of *Coscinodiscus crassus cum Placentæ;* also the appearance, according to J. Rattray,[12] of certain specimens of *C. robustus* from Santa Monica, Cal., wherein a striated border (of the valve) was "surrounded by a second more sharply defined but narrower band, with a slightly convex surface; . . . . at one place this band is interrupted and somewhat more convex on the two sides of the break. This gives it the appearance of an elastic spring enveloping the valve."

Our material representing *C. robustus* is from Sendai, Japan, and while rich in girdles, it has failed to afford one that was completely closed.

ACTINOCYCLUS.

We have studied the girdles of *A. Ehrenbergii* Ralfs. from Florida. The structure is essentially the same as that of *Coscinodiscus subtilis* as given in figs. 7 and 8 of Pl. XV. In addition, we have seen at least one secondary girdle apparently developing in a most interesting and curious manner into a girdle of full width. More observation is needed here before we feel warranted in

[11] J. Brun: *Diatomeés Especes Nouvelles Marines*, p. 21.
[12] J. Rattray: *A revision of the genus Coscinodiscus* Ehr. Edinburgh, 1890.

drawing any final conclusion; but the single example referred to would seem to indicate only one possibility, namely, that the secondary girdles do indeed eventually become indistinguishable from the primary.

AULACODISCUS.

In this genus the girdles are composed of hoops, imbricated as in *Melosira*, *Lauderia*, etc. The arrangement of the hoops and the location of the gaps are shown photographically in figs. 4 and 5 of Pl. XVI, where the first figure is of the upper side of a semi-frustule of *A. Kittonii*, and the second is of the lower side of the same specimen. The girdle is in this case composed of four hoops, but the number varies from two to six or even more in different individuals. The opening of the hoop next the valve is on the lower side, that of the next is on the upper side, the third on the lower, the fourth on the upper. The cleats, which may be anticipated here on all except the first hoop, have not been seen.

BIDDULPHIA.

The typical species, *B. lævis* Ehr., so abundant along the coasts, has a complicated system of hoops. Two oft-recurring shapes are shown in fig. 4, Pl. XVI. The cleat on the narrower hoop passes through the gap in the wide hoop and attaches itself to the valve within the sulcus. In fig. 3, Pl. XVI, is shown a frustule with three hoops in the outer girdle. In fig. 6, Pl. XV, is given diagrammatically, but with essential faithfulness, a frustule with two valves and four approximately equal girdles. No cleats could be discovered in the specimen from which this figure was constructed. The arrangement shown would certainly indicate the possibility that secondary girdles may function as primaries in the daughter-cells.

As to the location of the girdle gaps, it is worth remarking that in this and neighboring species the gaps and cleats are always situated almost vertically under the knobs of the valves—that is to say, at the ends of the oval diatom, not on the flat sides as in *Surirella*.

Diatoms With Closed Girdles.

Apparent or real exceptions to the open-girdle structure are noted as follows:

Synedra superba Kuetz. Whether the girdle is or is not closed

at both ends in this species remains quite doubtful. Certainly there is much appearance of complete closure in many specimens examined by us. In any case, the girdle is furnished with a stout hook-shaped cleat at one end, and generally at the other end with either precisely the same thing or else with two hooks only separable from each other with difficulty.

Arachnoidiscus Ehrenbergii Bailey. Such girdles of this species as we have examined have been narrow and comparatively thick. They are attached to the under side of the valve by an inward-bent rim of great tenuity, quite continuous all around the circle. No manipulation we could bring to bear has made any opening evident in either rim or girdle, and the girdles usually show as perfect and complete circles.

Triceratium favus Ehr. The girdles are attached by a rim like that in *Arachnoidiscus*. They are broader, however, and of a thickness that would make any opening or gap very obvious. Considering the close relationship now thought to obtain between *Triceratium* and *Biddulphia*, we confidently expected to find a similarity in girdle structure. Our material, though not in endless profusion, has not been exactly meagre. Yet we end by saying not only that we have not found any girdle gaps in *Triceratium*, but also that we do not believe any will be found. This is the more curious, since it would appear from published figures that *Lithodesmium* has possibly a complicated system of open girdles. But we have not examined the latter, and cannot state the facts as to this matter. It may be that the closed hoop structure is a characteristic of all the Triceratiinæ.

Terpsinœ musica Ehr. seems to have closed girdles. Being a large form, any opening ought to be seen with ease. If such exists, it is in the form of a very narrow slit at the end of the diatom, and so invisible in the specimens as usually mounted.

Isthmia nervosa Kuetz. This very large diatom has completely closed girdles. These are all the exceptions to the general rule that we have detected. Their importance is undeniable. Others among the Centricæ may quite possibly be found; though, if our present classification is not overrated as an expression of natural relationships, the probabilities are all in favor of the open-girdle structure in most of the genera intervening between *Melosira* and *Biddulphia*. As to the Pennatæ, terminal gaps may be expected in nearly all genera.

We desire to thank Messrs. J. E. Schultz, Lewis Woolman and C. S. Boyer for diatom material, and the last-named gentleman for certain references to the literature of diatoms.

EXPLANATION OF PLATES.

PLATE XV.

Fig. 1. *Surirella elegans* Ehr. *a*, inner primary girdle; *b*, outer primary girdle; *a'*, inner secondary girdle; *b'*, outer secondary girdle; *c*, arrangement of parts *in situ*; *d*, separated primary girdle; *e*, separated secondary girdle with cleat.

Fig. 2. *Pinnularia* sp. *a*, girdle on edge; *b*, girdle on flat side, distorted.

Fig. 3. *Rhabdonema adriaticum* Kuetz. *a*, primary girdle; *a'*, secondary girdle.

Fig. 4. *Eunotia major* Rab. *a*, primary girdle; *a'*, secondary girdle.

Fig. 5. *Nitzschia sigmoidea* Ehr. *a*, primary girdle; *b*, secondary girdle.

Fig. 6. *Biddulphia lævis* Ehr. Two valves and four girdles, the front of outer girdles broken away to show gaps on the farther side.

Fig. 7. *Coscinodiscus subtilis* Grun. A pair of primary girdles, with two secondaries in place.

Fig. 8. *Coscinodiscus subtilis* Grun. An inner primary girdle, with two secondaries adhering.

PLATE XVI.

Fig. 1. Valve view of girdle of *Coscinodiscus robustus* Grev. × 350.

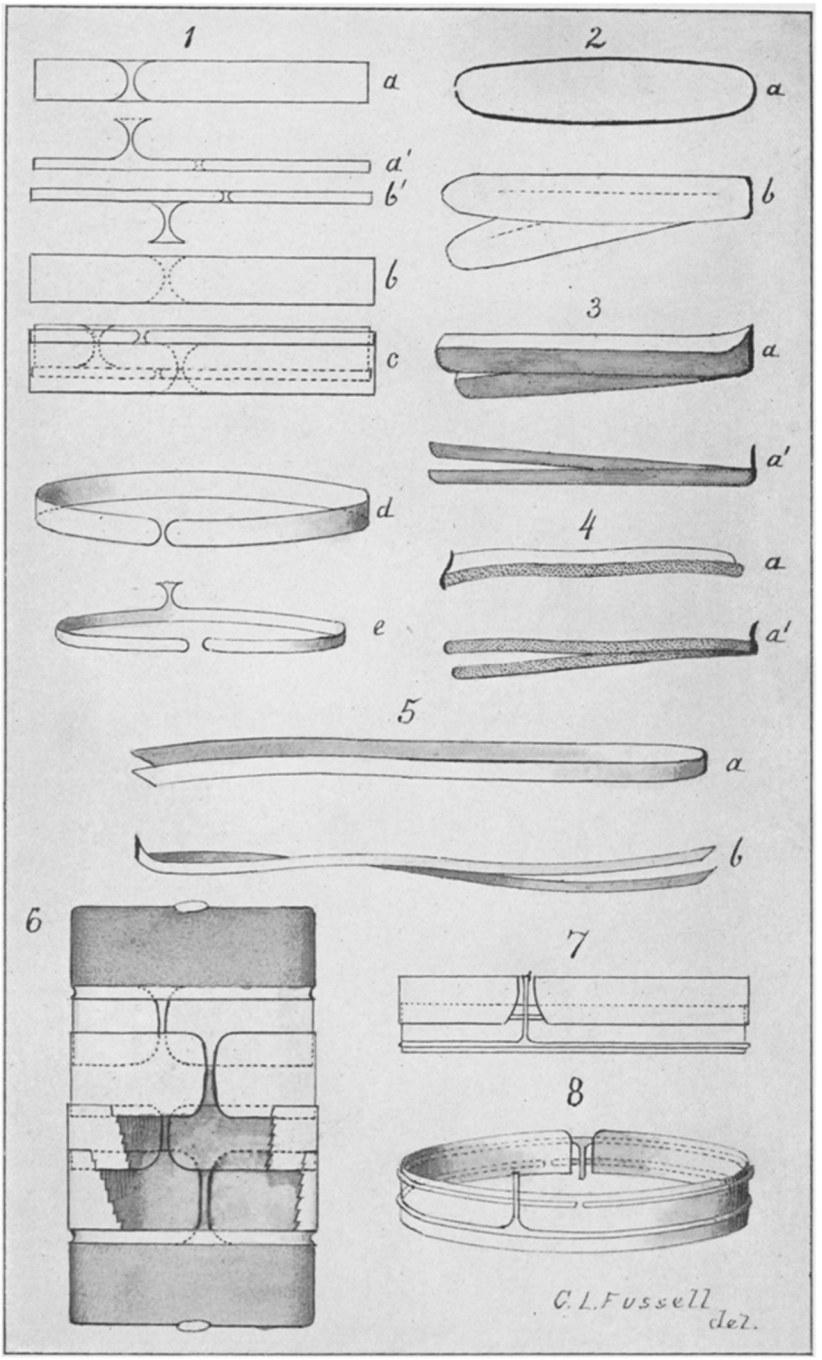
Fig. 2. Girdle view of girdle of *Coscinodiscus robustus* Grev. × 350.

Fig. 3. *Biddulphia lævis* Ehr. × 425. Showing three hoops in outer girdle.

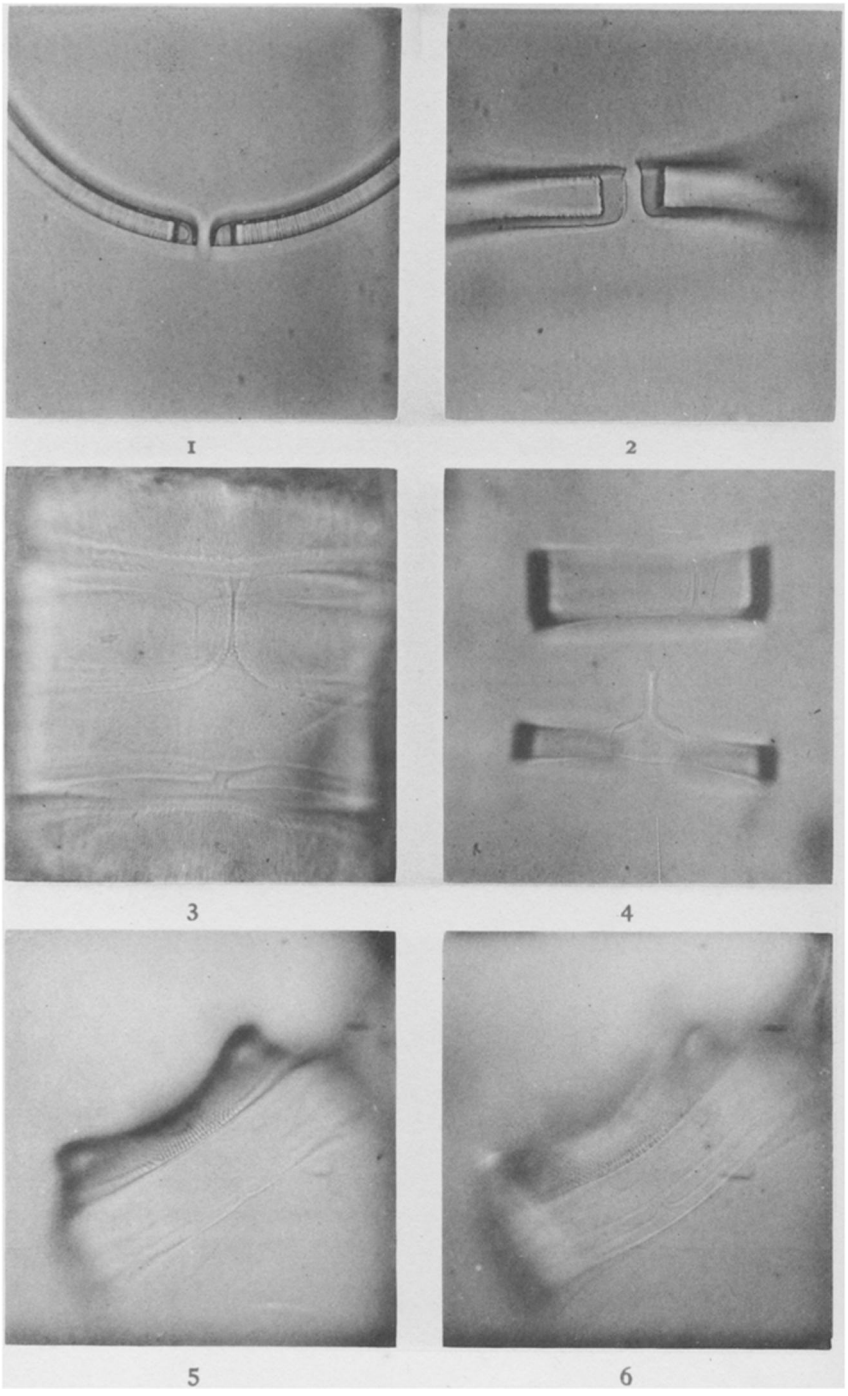
Fig. 4. *Biddulphia lævis* Ehr. A primary and a secondary girdle, the latter with cleat. × 200.

Figs. 5 and 6. *Aulacodiscus Kittonii* Arnott. × 370. A semi-frustule, mounted on its girdle, and photographed first on the side in contact with the cover-glass (fig. 5), then on the far side (fig. 6).

Photographed with Tolles ⅛ 1.20 N. A.



PALMER AND KEELEY. GIRDLE OF DIATOMS.



PALMER AND KEELEY. GIRDLE OF DIATOMS.